Downward Nominal Wage Rigidity & State-Dependent Government Spending Multipliers

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Abstract

Empirical studies that account for business cycle states often find that government spending multipliers are bigger in recessions than in expansions. This paper provides a theoretical explanation that downward nominal wage rigidity, which only interacts with recessions, can give rise to state-dependent spending multipliers. Consistent with Keynesian views, a demand stimulus in recessions is less likely to drive up the real interest rate and wages, and thus the reduced crowding-out and positive income effects from decreased unemployment enhances the expansionary effect of a government spending increase. The paper also finds some empirical evidence on state-dependent responses of real wages and consumption to a spending increase in line with the theoretical predictions.

Keywords: state-dependent government spending multiplier; fiscal multiplier; downward nominal wage rigidity; nonlinear DSGE models; New Keynesian models

JEL Codes: E31; E62; H30

1 Introduction

Do government spending multipliers differ in recessions and expansions? A burgeoning empirical literature provides evidence on business cycle state-dependent multipliers. The vast majority of empirical evidence finds larger multipliers in recessions than in expansions (e.g., Auerbach and Gorodnichenko (2012a, 2013), Bachmann and Sims (2012), Baum et al. (2012), Caggiano et al. (2015), and Fazzari et al. (2015)).

Despite empirical support, the theoretical channels through which government spending has larger fiscal multipliers in recessions than in expansions are less clear. Canzoneri

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1Some conflicting evidence also exists. Using long historical datasets, Owyang et al. (2013) and Ramey and Zubairy (forthcoming) do not find higher government spending multipliers in recessions for the U.S.. Caggiano et al. (2015) do not find much different multipliers between general recessions and expansions, but the difference is significant when comparing the multipliers in deep recessions to those in strong expansions.
et al. (2016) propose that countercyclical variation in bank intermediation costs can generate state-dependent spending multipliers, as a government spending increase reduces interest rate spreads, facilitating private borrowing in recessions. Also, Michaillat (2014) shows that increasing public employment in expansions raises labor costs and thus dampens the effectiveness of government spending to raise aggregate employment. Both theoretical channels are plausible, but their empirical importance is to be established. In this paper, we propose an alternative theoretical channel that downward nominal wage rigidity (DNWR) can contribute to the state-dependent government spending multipliers and verify this channel in data.

DNWR in data is well documented and shown to be prevalent. Using micro-level data of U.S. and 15 European countries, Dickens et al. (2007) estimate that on average 28 percent of the wage cuts that have taken place under flexible wage setting are averted by DNWR, and this fraction is almost 50 percent for the U.S. To see whether DNWR is discernible in macro-level data, Figure 1 presents employment, nominal hourly compensation, and labor productivity for the U.S. Except for the 1969 and 2001 recessions, labor productivity fell in every recession, yet the nominal hourly compensation largely increased even before the first quarter of 2009 for the the Great Recession, which started at the end of 2007. The average productivity decline for the seven recessions (since 1955) from the beginning quarter to the quarter of the lowest productivity within a recession is 1.2%, yet the nominal wage rate on average grows 3% and the real wage rate by 0.1% over the same periods. Our calculation confirms that both DNWR and downward real wage rigidity are generally present in U.S.

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2Canzoneri et al. (2016) document the government spending share is more negatively correlated with spreads in recessions and show the slope in regressing spreads on government spending shares is more negative in recessions than in expansions. These reduced form relationships are insufficient to conclude that a government spending increase lowers financial intermediate costs in data. Michaillat (2014) conducts a quantitative assessment on public employment multipliers using a calibrated model, without confronting the model predictions with data.

3Messina et al. (2010) use the same methodology and find that the share of workers affected by DNWR varies from 55% to 22% for the four European countries examined. Other papers present evidence on DNWR include Nickell and Quintini (2003) using the U.K. New Earning Survey data, Kaur (2014) using the data of daily agricultural labor in India, and Holden and Wulfsberg (2009a,b) using the data of 19 OECD countries. See Kim and Ruge-Murcia (2009) for a survey of earlier evidence on DNWR.

4All the data come from Bureau of Labor Statistics (BLS): Labor productivity are measured by output per hour (series PRS85006093); nominal hourly compensation includes employer expenditures for insurance and benefit programs and payments made in cash or in kind (series PRS85006103); employment is converted from total nonfarm employment (series CES0000000001) to an index series. Recession shades are those identified dates by the NBER’s Business Cycle Dating Committee.

5Real wage changes are computed from subtracting inflation from nominal wage growth rates, and inflation is calculated from the consumer price index published by BLS.
In this paper, we show how DNWR can generate business cycle-state dependent government spending multipliers. The analysis starts by presenting analytics from a simple log-linearized New Keynesian (NK) model to illustrate the key mechanisms that a government spending increase can be more expansionary in recessions where DNWR binds. It then moves to quantitative simulations using a general NK model with DNWR that is solved nonlinearly.

Intuitively, government spending can be more expansionary in recessions with DNWR than in expansions because a spending increase in a recession reduces unemployment and does not drive up the real interest rate as much as in an expansion. When a spending increase is injected in expansions that have full employment, it has the usual effects of rising goods demand, which makes firms hire more labor, driving up nominal and real wages. The increase in firms’ marginal cost generates inflation, which induces monetary authority to raise the nominal rate and hence the real rate. The rising real interest rate then generates the typical crowding-out on private demand, offsetting some of the original expansionary effect from government spending.

In recessions, DNWR prevents the nominal wage from falling. A spending increase can lower the real wages because of inflation from the spending increase. A muted real wage response does not drive firms’ marginal cost as much and hence induces less inflation and a real interest rate increase. The reduced interest rate increase leads to less crowding out in private demand, making a government spending increase more expansionary in recessions. In addition to less crowding out, DNWR in recessions enhances the expansionary effects of a spending increase also through reduced unemployment. As the effective real wage is higher than the equilibrium (market-clearing) real wage, DNWR creates a discrepancy between the desired labor supply and labor demand, generating involuntary unemployment in recessions. With additional government demand, the effective real wage falls and the market-clearing real wage rises, which reduces the discrepancy between desired labor supply and demand. Lower unemployment increases households’ income, raising consumption, which further amplifies recessions, consistent with the finding in Abbritti and Fahr (2013).
the expansionary effects of government spending.

In the quantitative analysis, we quantify that the impact multiplier in a recession can be bigger than 1 (at 1.7) while it is only 0.6 in an expansion under the baseline specification. Our baseline adopts the GHH preference (Greenwood et al. (1988)) that eliminates the wealth effect on labor supply. Sensitivity analysis examines another commonly used KPR preference (King et al. (1988)). The qualitative results that DNWR leads to larger government spending multipliers in recessions than in expansions remain standing, although the difference becomes smaller with the KPR preference.

To show that the key channels through which DNWR can affect government spending effects are operative in data, we follow Auerbach and Gorodnichenko’s (2012a) method to estimate a regime-switching structural VAR in an expanded system with real wages and consumption. Our estimation confirms that the spending multipliers can be bigger than 1 in recessions while much smaller than 1 in expansions as found in Auerbach and Gorodnichenko. In addition, we find that to a government spending increase, real wages are lower and consumption is much higher in recessions than in expansions. This suggests that the DNWR is a plausible cause to drive state-dependent multipliers in data.

This paper adds to the booming literature in state-dependent government spending effects. Aside from business cycles, the states have been examined also include monetary policy and government indebtedness. Davig and Leeper (2011) and Leeper et al. (forthcoming) find that when monetary policy is passive and fiscal policy is active (in the sense of Leeper (1991)), government spending multipliers can be much bigger than 1 and consumption can respond positively to a spending increase, in contrast to a much smaller multiplier in the alternative regime of active monetary and passive fiscal policy. When the zero lower bound of the nominal interest rate binds, Christiano et al. (2011) and Erceg and Lindé (2014) find that government spending multipliers can be much bigger when the economy is in a liquidity trap than in normal conditions. On government indebtedness, Ilzetzki et al. (2013) and Nickel and Tudyka (2014) provide empirical evidence that spending multipliers are small or even negative in highly-indebted economies. Also, Bi et al. (2016) provide a theoretical account
to explain how current government debt levels can affect expectations about future fiscal adjustments, which in turn affect current spending effects. Lastly, Sims and Wolf (2017) study state-dependent government spending effects, where the states consist of a variety of structural and policy shocks for conducting the welfare analysis of countercyclical government spending.

2 The Model

We outline a simple New Keynesian (NK) model with elastic labor supply and inelastic capital. The central frictions in the model are price rigidities and downward nominal wage rigidity as in Schmitt-Grohé and Martín (2016).

2.1 Households

A representative household with a GHH preference (Greenwood et al. (1988)) chooses composite consumption \(c_t\), labor \(n_t\), and government debt \(B_t\) to maximize utility:

\[
\max \sum_{t=0}^{\infty} d_t \frac{c_t - \chi(n_t)^{\varphi}}{1 - \sigma},
\]

where \(\sigma\) is the inverse of intertemporal elasticity of substitution, and \(\varphi\) governs the Frisch elasticity of labor supply. Define \(d_t = \prod_{j=1}^{t} \beta_j\) for \(t > 0\), and \(d_0 = 0\), where \(\beta_j\) is the time-varying discount factor in period \(j\). The composite consumption is aggregated from differentiated goods \(c_t(i)\) with the Dixit and Stiglitz (1977) aggregator

\[
c_t = \left(\int_0^1 c_t(i)^{\frac{\sigma - 1}{\sigma}} d\theta\right)^{-\frac{\sigma}{\sigma - 1}}, \quad \theta > 1
\]

The demand function for each good \(i\) is

\[
c_t(i) = \left[\frac{P_t(i)}{P_t}\right]^{-\theta} c_t,
\]
where $P_t(i)$ is the nominal price for $c_t(i)$ and $P_t$ is the aggregate price level. The household’s budget constraint is

$$c_t + \frac{B_t}{P_t} + z_t = \frac{W_t n_t}{P_t} + \frac{R_{t-1} B_{t-1}}{P_t} + \int_0^1 \Gamma(i),$$

where $W_t$ is the nominal wage rate, $B_t$ is one-period nominal bond holding, $R_{t-1}$ is the nominal interest rate between $t - 1$ and $t$, $\Gamma(i)$ is the profit from firm $i$, and $z_t$ is lump-sum taxes. The transversality condition for bond must hold, implying

$$\lim_{T \to \infty} E_t q_{t,T} \frac{B_T}{P_T} = 0,$$

where $q_{t,T} \equiv R_{t-1}/(P_T/P_t)$.

To model DNWR, we assume that

$$W_t \geq W_{t-1},$$

which is one case embedded in a general setup in Schmitt-Grohé and Martín (2016), where $W_t \geq \gamma W_{t-1}$ and $\gamma > 0$. Our setup implies that $W_{t-1}$ is a price floor for nominal wages. DNWR prevents the labor market from clearing when the price floor binds, leading to involuntary unemployment, computed as follows:

$$u_t = n^*_t - n_t.$$ 

Unemployment can arise in this model when an economy is hit by some contractionary shocks that lower the equilibrium market clearing wage if there is no DWN. Thus, the unemployment modeled here is cyclical; the model does not capture frictional and structural unemployment. Note that our setup of DNWR implicitly assumes $\gamma = 1$. The analytical linear results obtained here, however, would go through if $\gamma$ takes other value, because $\gamma$ is dropped in the linearized equilibrium of the current model. Later in the quantitative analysis, we explore the implications of $\gamma \neq 1$ for different degrees of DNWR.
The household’s optimization condition for desired labor supply is

$$\chi \varphi(n^*_t)^{\varphi-1} = \frac{W_t}{P_t} \equiv w_t$$

(8)

where labor supply $n^*_t$ is determined by the real wage rate ($w_t$), but the household may not be able to work the desired number of hours. In each period, wages and employment must satisfy the slackness condition

$$(n^*_t - n_t)(W_t - W_{t-1}) = 0,$$

(9)

which says that either the labor market has to clear ($n^*_t = n_t$) or DNWR has to bind ($W_t = W_{t-1}$).

### 2.2 Firms

The economy has two types of firms: a representative competitive final goods producer and monopolistically competitive intermediate goods producers who produce a continuum of differentiated goods, indexed by $i$. A final goods producer produces the composite good using the technology:

$$y_t = \left[ \int_0^1 y_t(i)^{1-\frac{1}{\sigma}} di \right]^{\frac{\sigma}{\sigma-1}}.$$  

(10)

The intermediate goods firm $i$ produces using labor with a linear technology:

$$y_t(i) = an_t(i),$$

(11)

where $a$ is the common technology. Cost minimization implies that each intermediate firm faces the same real marginal cost:

$$mc_t = \frac{w_t}{a}.$$  

(12)

Following Calvo (1983), a fraction of $1 - \omega$ intermediate firms can change their nominal prices each period. Firms which get a chance to change their prices at period $t$ by choosing
their price level to maximize the expected sum of discounted future real profits:

\[
\max_{P_t(i)} E_t \sum_{j=0}^{\infty} (\omega \beta)^j \frac{\lambda_{t+j}}{\lambda_t} \left[ \frac{P_t(i)}{P_{t+j}} - mc_{t+j} \right] y_{t+j}(i),
\]  

subject to

\[
y_t(i) = \left[ \frac{P_t(i)}{P_t} \right]^{-\theta} y_t.
\]

The first order condition to determine the optimal price \( P_t^* \) is given by:

\[
\frac{P_t^*}{P_t} = \frac{\theta}{\theta - 1} \frac{E_t \sum_{j=0}^{\infty} (\omega \beta)^j \lambda_{t+j} y_{t+j} mc_{t+j} \left( \frac{P_t}{P_{t+j}} \right)^{-\theta}}{E_t \sum_{j=0}^{\infty} (\omega \beta)^j \lambda_{t+j} y_{t+j} \left( \frac{P_t}{P_{t+j}} \right)^{1-\theta}},
\]

which can be rewritten as

\[
\frac{P_t^*}{P_t} = \frac{\theta}{\theta - 1} \frac{k_{1t}}{k_{2t}},
\]

where \( k_{1t} = \lambda_t y_t mc_t + \omega \beta E_t k_{1t+1} \pi_{t+1}^\beta \) and \( k_{2t} = \lambda_t y_t + \omega \beta E_t k_{2t+1} \pi_{t+1}^{\beta-1} \). Using the aggregate price index \( P_t^{1-\theta} = (1 - \omega)(P_t^*)^{1-\theta} + \omega P_{t-1}^{1-\theta} \), inflation is solved as

\[
\pi_t = \left[ \frac{1}{\omega} - \frac{1 - \omega}{\omega} \left( \frac{P_t^*}{P_t} \right)^{1-\theta} \right]^{\frac{1}{\pi_t}} = \left[ \frac{1}{\omega} - \frac{1 - \omega}{\omega} \left( \frac{\theta}{\theta - 1} \frac{k_{1t}}{k_{2t}} \right)^{1-\theta} \right]^{\frac{1}{\pi_t}}.
\]

Compute aggregate labor as \( n_t = \int_0^1 n_t(i) di \). Linear aggregation of individual market clearing conditions implies the aggregate production function is given by

\[
y_t = \frac{an_t}{\Delta_t},
\]

where \( \Delta_t \) is the relative price dispersion, defined by \( \Delta_t = \int_0^1 \left[ \frac{P_t(i)}{P_t} \right]^{-\theta} di \). Using the aggregate price index, one can derive that \( \Delta_t \) evolves according to

\[
\Delta_t = (1 - \omega) \left( \frac{P_t^*}{P_t} \right)^{-\theta} + \omega \pi_t^\theta \Delta_{t-1}.
\]
2.3 Fiscal and Monetary Policy

In the analytical model, we assume that government spending, \( g_t \), follow a simple stochastic process:

\[
g_t = g e^{\varepsilon_g^t},
\]

where \( \varepsilon_g^t \sim \text{i.i.d. } N(0, \sigma_g^2) \). Throughout the paper, a variable without a time subscript indicates its value in the steady state. The government budget constraint is

\[
z_t + \frac{B_t}{P_t} = g_t + \frac{R_{t-1}B_{t-1}}{P_t}.
\]

The monetary authority follows a simple Taylor rule, which adjusts the nominal interest rate, \( R_t \), in response to the inflation rate

\[
R_t = \max(R\pi_t^\phi, 1),
\]

with \( \phi > 1 \), implying that the interest rate responds to inflation more than one for one. We imposes a lower bound restriction on \( R_t = 1 \) because we intend to focus on the equilibrium of an active monetary policy and passive fiscal policy in the sense of Leeper (1991).

The aggregate resource constraint is

\[
y_t = c_t + g_t.
\]

The equilibrium conditions of the analytical model consist of equation (A.1) to (A.12) in Appendix A.

3 Analytics of State-Dependent Multipliers

Before launching into the quantitative simulations in a fully-nonlinear model, this section uses a linear approximation that yields an analytical solution for government spending multipliers. The analysis establishes that DNWR aggravates a recession, and the channels via which
government spending can become more expansionary in recessions with DNWR than in expansions. The analysis for the analytical model uses the discount factor shock as the source of business cycles (as in Christiano et al. (2011)). Also, to simplify derivation, we assume that the steady-state inflation ($\pi$) and labor ($n$) are both 1. A variable with a “$\hat{}$” indicates the percent deviations from its steady state value.

To derive the “IS” equation, substitute the monetary policy rule (22) to the intertemporal Euler equation (A.3). Log-linearization yields

$$\hat{\lambda}_t = E_t \hat{\lambda}_{t+1} + \alpha \hat{\pi}_t - E_t \hat{\pi}_{t+1} + E_t \hat{\beta}_{t+1}. \quad (24)$$

Also, log-linearization of the marginal utility of consumption (A.1) yields

$$\hat{\lambda}_t = -\frac{\sigma c}{c - \chi n^\varphi} \hat{c}_t + \frac{\sigma \chi n^\varphi}{c - \chi n^\varphi} \hat{n}_t. \quad (25)$$

Define the steady-state government spending to output ratio as $s_g \equiv \frac{g}{y}$; then the steady-state consumption $c = (1 - s_g) y$. Solving the model-implied parameter $\chi$ as $\frac{\theta - 1}{\theta \varphi}$, equation (25) becomes

$$\hat{\lambda}_t = -\frac{\sigma \varphi \theta (1 - s_g)}{\theta \varphi (1 - s_g) - \theta + 1} \hat{c}_t + \frac{\sigma \varphi (\theta - 1)}{\theta \varphi (1 - s_g) - \theta + 1} \hat{n}_t. \quad (26)$$

From the aggregate resource constraint (23) and the production function (18), we can get,

$$\hat{c}_t = \frac{1}{1 - s_g} \hat{y}_t - \frac{s_g}{1 - s_g} \hat{g}_t \quad (27)$$

$$\hat{n}_t = \hat{y}_t. \quad (28)$$

Substitute (25), (27), and (28) to (24) to obtain the IS equation

$$\hat{y}_t = E_t \hat{y}_{t+1} - \Psi (\alpha \hat{\pi}_t - E_t \hat{\pi}_{t+1}) + \theta s_g (\hat{g}_t - E_t \hat{g}_{t+1}) - \Psi E_t \hat{\beta}_{t+1} \quad (29)$$

where $\Psi = \frac{\theta \varphi (1 - s_g) - \theta + 1}{\sigma \varphi}$. Next, combine (16) and (17) and log-linearize to obtain the Phillips
\[
\hat{\pi}_t = \frac{(1-\omega)(1-\omega\beta)}{\omega} m_c t + \beta E_t \hat{\pi}_{t+1}
\] (30)

The IS equation, (29), and the Phillips curve, (30), fully characterize the equilibrium.

To proceed, we define business cycle states of the economy as follows.

**Definition 1.** At period \( t \), the economy is in expansions if \( \hat{\beta}_t = b_L \) and in recessions if \( \hat{\beta}_t = b_H \), where \( b_L < 0 \), \( b_H > 0 \), and \( b_L = -b_H \).

When \( \hat{\beta}_t = b_L \), agents are less patient than in the steady state, which makes households consume more and drive up intermediate goods firms’ demand to produce more, leading to an expansion, and vice versa for \( \hat{\beta}_t = b_H \) to produce a recession.

In reality, the length of an expansion is typically longer than that of a recession. Thus, we assume people in an expansion are more likely to expect that the same state will continue the next period than in a recession. To capture this idea and to make the solution tractable, we make the following expectation assumptions about future discount factors in the two states.

**Assumption 1.** When an economy is in an expansion, \( P(E_t \hat{\beta}_{t+1} = b_L | \hat{\beta}_t = b_L) = 1 \), \( P(E_t \hat{\beta}_{t+2} = b_L | E_t \hat{\beta}_{t+1} = b_L) = 0.5 \), and \( P(E_t \hat{\beta}_{t+2} = b_H | E_t \hat{\beta}_{t+1} = b_L) = 0.5 \). When an economy is in a recession, \( P(E_t \hat{\beta}_{t+1} = b_H | \hat{\beta}_t = b_H) = 1 \), \( P(E_t \hat{\beta}_{t+2} = b_H | E_t \hat{\beta}_{t+1} = b_H) = 0 \), and \( P(E_t \hat{\beta}_{t+2} = b_L | E_t \hat{\beta}_{t+1} = b_H) = 1 \).

Assumption 1 says that when an economy is in an expansion at \( t \), households expect that the expansion will be in place for \( t + 1 \), and they expect a 50% of probability that it switch to a recession at \( t + 2 \). If an economy is in a recession at \( t \), then they also expect that the economy would continue to be in a recession at \( t + 1 \) but they expect the economy to switch to an expansion at \( t + 2 \) with a probability 1. Later in the quantitative analysis, we adopt general AR(1) specifications on the shocks and households will form expectations based on the stochastic process of discount factor shocks.

Under Definition 1 and Assumption 1, we obtain the following proposition.
Proposition 1. Without DNWR, the government spending multiplier is given by

\[ M_y = \frac{\omega \theta}{\omega + \Psi \alpha (1 - \omega)(1 - \omega \beta)(\varphi - 1)}, \]  

(31)

and the multipliers are the same in expansions and recessions.

Proof. See Appendix B.1.

Under the common values calibrated for the Frisch elasticity of labor elasticity ($\varphi \geq 2$, implying the Frisch elasticity is equal or smaller than 1) and the government to output share ($s^g << 0.5$), $\Psi = \theta \varphi (1 - s^g) / \sigma > 0$, and hence $M_y > 0$. This means that the government spending multiplier is positive under full employment in our model.

Note that under flexible prices ($\omega = 0$), it can be seen from (31) that the multiplier is zero. Under the GHH preference without nominal price stickiness, both labor demand and labor supply curves do not shift outward when government spending increases. The combination of the GHH preference and nominal price stickiness produces positive government spending multipliers. In response to higher aggregate demand (as prices do not rise fully immediately), the labor demand curve shifts outwards, leading to a higher wage rate and equilibrium labor. This shifting is bigger as the prices are more sticky (a bigger $\omega$), which leads to a bigger spending multiplier.\(^6\)

To see the role of DNWR in state-dependent government spending effects, in the analysis below we consider a scenario where a sufficiently large discount factor shock hits at time $t$ to trigger binding DNWR, similar to the assumption made in Christiano et al. (2011).

Assumption 2. The economy at $t - 1$ has full employment (i.e., DNWR does not bind) and $\hat{w}_{t-1} > 0$. At time $t$, the economy is hit by a discount factor shock—$b_H$. Then, from Assumption 1, $E_t \beta_{t+1} = b_H$ and $E_t \beta_{t+2} = b_L$. Let $b_H$ be sufficiently contractionary to make DNWR bind at $t$, while $b_L$ is sufficiently expansionary to generate time $t$ expectation for full employment at $t + 2$.

\(^6\)As shown by Monacelli and Perotti (2008) with nominal price stickiness, the size of the multiplier increases as the degree of complementarity between hours and consumption rises. Such complementarity is the highest without the wealth effect on labor supply, as in GHH preferences. Under this setup, a wide range of parameterizations can generate large multipliers that are above one.
DNWR results in a real rigidity. To see this, rewrite (6) in real terms,

\[ w_t \geq \frac{w_{t-1}}{\pi_t}, \quad (32) \]

which suggests that inflation at \( t \) can lower the floor of the real wage rigidity. Log-linearizing (32) yields

\[ \dot{w}_t \geq \dot{w}_{t-1} - \dot{\pi}_t. \quad (33) \]

Let * denote the full-employment equilibrium value for an endogenous variable (i.e., the equilibrium values as if there were no DNWR so desired labor supply equals labor demand). Then, \( \dot{w}_t^* \) is the full-employment wage rate, and DNWR is triggered when

\[ \dot{w}_t^* < \dot{w}_{t-1} - \dot{\pi}_t. \quad (34) \]

In this circumstance, the prevailing wage rate is \( \dot{w}_t = \dot{w}_{t-1} - \dot{\pi}_t > \dot{w}_t^* \). In a recession, a contractionary discount factor shock as a negative demand shock lowers inflation and \( \dot{w}_t^* \) (because reduced goods demand reduces labor demand and hence full-employment wages). From (34), it can be seen that a smaller \( \dot{w}_t^* \) and a lower inflation (which increases the real wage floor), making DNWR more likely to bind.\(^7\)

In our model (as well as likely in reality), DNWR aggravates a recession. A contractionary discount factor shock discourages consumption and suppresses aggregate demand. The price level falls somewhat despite nominal price rigidity. DNWR leads to a smaller decline in the real wage. As a result, labor, as determined firms’ demand, and thus output fall more than otherwise without DNWR. Although households in the economy with DNWR earns a higher wage rate than in one without DNWR, the rise of unemployment has a negative income effect, which lowers consumption more, leading to a more sever recession than otherwise.

**Proposition 2.** Under Assumption 2, the government spending multiplier of output in a

\(^7\)To see explicitly how a contractionary discount factor shock lowers the full-employment wage, note that in a recession \( E_0 \dot{\beta}_{t+1} = b_H \) from Assumption 1. By combining (B.1) and (B.4) in Appendix B.1, we have the full-employment wage \( \dot{w}_t^* = (\varphi - 1)A_y \dot{\beta}_t + (\varphi - 1)B_y b_H \), where \( (\varphi - 1)B_y < 0 \).
recession with DNWR \((M_{y}^{DNWR})\) is bigger than that in an expansion:

\[
M_{y}^{DNWR} = \theta > M_{y}.
\]  (35)

**Proof.** See Appendix B.2.

A bigger government spending multiplier in a recession with DWNR can be understood from the result that DWNR deepens a recession. If there were no DNWR, in response to a \(b_{H}\), the real wage rate falls until the labor market clears. The declined real wage also implies that goods prices adjust downward in a recession, which mitigates some negative effect on goods demand from a contractionary discount factor shock. With DNWR, as the real wage cannot fall below its floor, unemployment suggests a bigger labor decline than otherwise without DNWR. Also, a smaller decline in real wage means that price cannot fall as much as without DNWR, amplifying the negative effect of the discount factor shock on goods demand. Thus, with a more severe decline in goods demand, firms produce less than otherwise without DNWR.

In an expansion, a government spending increase has the usual effect that it increases labor and output. In a NK model, more government spending raises goods demand, which prompts intermediate-goods producers to hire more labor, raising the real wage and hence the real marginal cost. Firms thus increases goods prices, pushing up inflation. Under active monetary policy, the real interest rate increases, crowding out some private demand, resulting in a consumption decline. If, however, the spending increase is injected in a recession with DNWR, higher aggregate demand shrinks unemployment as higher labor demand from a fiscal expansion increases labor demand relative to the case without a fiscal expansion. In addition, when the size of a spending increase is not big enough to dissipate DNWR (as assumed here), a spending increase does not drive up the real wage. In this simple model with i.i.d. government spending shocks, a one-time exogenous increase in government spending also does not increase inflation as agents do not expect higher future inflation. As inflation does not rise, the monetary authority does not raise the nominal interest rate, which leaves
the real rate unchanged. Unlike the government spending increase in an expansion, the real wage and the real interest rate both do not rise in response to a government spending increase.

The different responses of unemployment and the real interest rate to a government spending increase in different business cycle states is formally presented below.

**Proposition 3.** In an expansion, a government spending increase has no effect on unemployment \( \frac{du_t}{dg_t} = 0 \), but it raises the real interest rate \( \frac{dr_t}{dg_t} > 0 \). In a recession with DNWR, a government spending increase reduces unemployment \( \frac{du_t}{dg_t} < 0 \), but it does not drive up the real interest rate \( \frac{dr_t}{dg_t} = 0 \).

**Proof.** See Appendix B.3.

The result that the real rate does not rise to a government spending increase in a recession is a special case. Later in the quantitative analysis, we see that once a general government spending process is adopted (like an AR(1)), current inflation can rise due to expected higher future government spending. The result that government spending multiplier is bigger in recessions than in expansions, however, remains standing.

### 4 Quantitative Analysis

The above analysis highlights the key mechanisms that DWNR can generate business-cycle state dependent multipliers. The qualitative analysis, while illuminating, do not produce empirically sensible results as many stark assumptions (such as i.i.d. spending shocks and stylized expectations for discount factors) are necessary to manage analytical solutions. In this section, we go back to a common NK model and obtain a fully nonlinear rational expectation solution. It first quantifies government spending multipliers. Next, it studies how the degrees of DNWR matter for government spending effects and explores an alternative preference—the KPR preference \((\text{King et al. (1988)})\)—to see whether the wealth effect of labor supply can alter the result of state dependent multipliers. Lastly, it derives the implication of government spending sizes in recessions in terms of its effectiveness to facilitate
economic recoveries.

The quantitative model modifies the setup in Section 3 with the following changes. We assume that both discount factor and government spending shocks follow AR(1) processes:

\[
\ln \frac{\beta_t}{\beta} = \rho_{\beta} \ln \frac{\beta_{t-1}}{\beta} + \varepsilon^\beta_t, \\
\ln \frac{g_t}{g} = \rho_g \ln \frac{g_{t-1}}{g} + \varepsilon^g_t,
\]

where \( \varepsilon^\beta_t \sim_{i.i.d.} N(0, \sigma^2_\beta) \) and \( \varepsilon^g_t \sim_{i.i.d.} N(0, \sigma^2_g) \). Our baseline simulation exercises inject sufficiently contractionary discount factor shocks (i.e., positive \( \varepsilon^\beta_t \)'s) to generate a recession state where DNWR binds. Also, on DNWR we return to the original flexible specification in Schmitt-Grohé and Martín (2016),

\[
W_t \geq \gamma W_{t-1},
\]

where \( 0 \leq \gamma \leq 1 \), and the price floor for nominal wages are \( \gamma W_{t-1} \). When \( \gamma = 0 \), nominal wages perfectly flexible, and when \( \gamma \to 1 \), they are absolutely downward rigid.

4.1 Calibration and the Solution Method

We use the following baseline parameter values, typical of those in the macro literature. The quarterly real interest rate is set to 1% so \( \beta = 0.99 \). Preferences over consumption are logarithmic, so \( \sigma = 1 \). A Frisch labor elasticity of 0.5 implies that \( \varphi = 3 \), and \( \chi \) is pinned down by the assumption that the steady-state labor is \( n = 1 \). We assume that intermediate goods firms’ price markup is 15 percent, so \( \theta = 7.67 \). The degree of price stickiness, \( \omega \), is set to be 0.75, implying an average price rigidity is one year. Steady-state government spending to output is 0.2. To calibrate the stochastic process of government spending, we estimate a simple AR(1) process using detrended U.S. data, which yield \( \rho_g = 0.81 \) and \( \sigma_g = 0.0096 \).

Given a wide range of persistence in the discount factor used in the literature—e.g., 0.18 in

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\( ^8 \)Real government spending is measured as the sum of government consumption expenditure and gross government investment (NIPA Table 3.1, lines 21 and 39) less consumption of fixed capital (NIPA Table 3.1, line 42), deflated by the GDP deflator. The original data are detrended by the HP filter.
Fernández-Villaverde et al. (2015b) and 0.80 in Fernández-Villaverde et al. (2015a), we set $\rho_\beta = 0.6$ and $\sigma_\beta = 0.0008$. Monetary policy follows a Taylor principle with $\phi = 1.5$.

To calibrate the degree of DWNR, $\gamma$, we follow Schmitt-Grohé and Uribe’s (2016) method. Since $\gamma$ represents a constraint that captures the lower bound of the nominal wage, we resort to the largest economic downturn in the postwar U.S. history—the Great Recession—to calibrate $\gamma$. Around this recession, the peak nominal hourly compensation occurs in 2008Q4 (an index number of 100.2) and the trough occurs in 2009Q1 (97.7), this implies a ratio of 0.975. Since changes in nominal wages may also reflect real economic growth, we divide this ratio by the long-run average quarterly growth rate in real GDP from 1947 to 2015 to obtain $\gamma = 0.96$.

The full nonlinear model is solved using the monotone mapping method, a numerical algorithm based on Coleman (1991) and Davig (2004). This method discretizes the state space, which requires a set of initial guess and finds a fixed point in decision rules for each point in the state space. Let $S_t$ denote the state space at date $t$, the solutions converge to functions that map the minimum set of state variables, including the current discount factor and government spending, and lagged relative price dispersion and real wage rate ($S_t = (\beta_t, g_t, \Delta_t - 1, w_{t-1})$) into values for the endogenous variables ($n_t, k_{1t},$ and $k_{2t}$ in (16)). Appendix C describes the procedure to solve the nonlinear model.

### 4.2 Quantifying State-Dependent Multipliers

For obtaining an analytical solution, previous analysis for expansion states focuses on one particular discount factor value ($\hat{\beta}_L = b_L < 0$, see Assumption 1), which drives the economy above the steady state. DNWR in our model only operates in recessions, and our comparison of spending multipliers in various states can be thought as multiplier differences when DNWR binds or not. Thus, this section broadly defines that the expansion states include the steady state.

To facilitate comparison, our simulations pick two particular states representing a reces- 

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9The value of $\sigma_\beta$ matters less for our simulations. A relatively small $\sigma_\beta$ is chosen so that it is less likely to trigger the zero lower bound and ensures determinacy.
sion and an expansion. In Figure 2, the recession state (solid lines) is generated by injecting a contractionary discount factor shock at time 0, which leads the discount factor to rise by 2% above its steady-state level ($\beta$ from 0.99 to 1.01). From time -5 to -1, we inject a series of expansionary (negative) discount factor shocks, so that the real wage at time -1 is 6.80% above the steady state.\(^{10}\) Combining a high lagged real wage and a contractionary discount factor shock, DNWR binds at time 0, leading to 6.45% unemployment rate and $-5.45\%$ output gap. In Figure 2, the expansion state (dashed lines) starts from the steady state at time 0. In both states, government spending increases by 1% of the steady-state level at time 0, following the process of (37). As the initial states are different, the units are measured by gaps between paths with and without the government spending shock, scaled by the deterministic steady-state values, except for unemployment and the discount factor. The unemployment rate is in level difference, and the discount factor is in percent deviation from the steady state. Since the expansion state has full employment with or without the spending shock, the difference in the unemployment rate stays at zero throughout the horizon.

From Figure 2, we can see the main differences between the two states lie in unemployment, output, the wage rate, inflation, and the real interest rate as in the analytical model. In either state, government spending increases labor and output, but it is much more expansionary in the recession than in the expansion state. Output rises by 0.34% of their steady-state values in the recession, compared to only 0.11% in the expansion. Surprisingly, the short-run consumption responses move in the opposite directions: on impact it rises by 0.18% in the recession while drops by 0.11% in the expansion. Table 1 reports the cumulative government spending multipliers for output and consumption in the two states, computed as

$$\sum_{i=1}^{k} r_{t+i-1}^{-1} \triangle r_{t+i-1}, \quad x \in \{y, c\}$$

where $\triangle$ denotes level changes relative to a path without government spending increase, and $r_t = E_t \frac{R_t}{\pi_{t+1}}$ is the real interest rate. The impact multiplier for output (consumption) is 1.71

---

10 From (38), it can be seen that the higher $\bar{w}_{t-1}$ is, the easier that DNWR can bind. We set $\{\bar{A}\}_{t=-5}^{0} = \{-0.87\% - 1.38\% - 1.69\% - 1.88\% - 1.99\% - 2.01\%\}$.
in recession versus 0.57 (−0.43) in expansion. This quantitative assessment is roughly in line with the estimates by Auerbach and Gorodnichenko (2012b). Their baseline results have the short-run (the first year) government spending multipliers are roughly between 0 and 0.5 in expansions, and between 1 and 1.5 in recessions.\footnote{Our longer term multipliers are not directly comparable to those in Auerbach and Gorodnichenko (2012b) as their empirical estimates are periodic multipliers and we have cumulative multipliers.}

The earlier analysis explains why the output multiplier is bigger in recessions than in expansions. Here we explain why consumption can have opposite responses in different states. The very different short-run consumption responses in the two states can be explained from the real interest rate channel and the positive income effect resulting from reduced unemployment in recessions. In the expansion state, the consumption decline can be mainly explained by the interest rate channel. As in the analytical model, government spending adds to goods demand and drives up inflation despite sluggish price adjustments. As monetary authority raises the nominal rate more than the inflation increase, the real interest rate rises and consumption falls.

In the recession state, this interest rate channel is operating, but a government spending increase in the recession state has positive income effects, resulting from reduced unemployment. On the one hand, like in the expansion state, a positive government spending shock today raises the expected goods demand and expected real wages and inflation. This expectation is, however, discounted in the recession state, as DNWR remains binding in the first two periods. Current inflation thus rises less in recession than in expansion. Consequently, the central bank does not raise nominal interest rate as much, resulting in a smaller real interest rate increase. On the other hand, the rising inflation in the recession state effectively lowers the real wage floor \((\gamma^{\mu_{t-1}})\) implied by (38), further increasing the labor demand of firms. The reduced unemployment increases households’ income, generating a positive effect on consumption, dominating negative consumption from the rising real interest rate. The positive consumption response in recession helps explain why government spending is more stimulative in the recession state. Instead of crowding out private demand in the expansion state, government spending in the recession state can raise private demand, enhancing its
effectiveness as a demand stimulus.

Our positive consumption response provides a theoretical alternative to reconcile with empirical VAR evidence that a government spending increase crowds in consumption (as found in Fatas and Mihov (2001), Blanchard and Perotti (2002), and Bouakez and Rebei (2007)), without resorting to nonsavers (as in Gali et al. (2007), Colciago (2007), and Furlanetto (2011)) or complementarity between consumption and government spending (as in Bouakez and Rebei (2007)) to generate the crowding-in effect. The result that DNWR can generate the positive consumption response in recessions depends on the relative strength of negative wealth effects from expecting higher government spending and positive income effects from reduced unemployment. The relatively importance of the income effect and other channels in explaining observed positive consumption response remains to be verified empirically.\footnote{Monacelli and Perotti (2008) also find that with the GHH preference without wealth effect on labor supply, it is possible to have government spending “crowd in” private consumption.}

A noticeable difference between the analytical model and the quantitative model is on the response of the real interest rate in recessions: The real interest rate stays the same in the analytical model but increases in the quantitative model. The difference is driven by the process of government spending. In the quantitative model, the government spending increase is persistent. This means that the expectation of higher future demand would drive up the current inflation further relative to the case of i.i.d. spending shocks. The higher current inflation then generates a higher nominal and hence real interest rate increase. Despite the rising real interest rate, its magnitude is substantially smaller than the increase in the expansions state (see Figure 2) and hence the crowding-out effect is also smaller. Thus, as the positive income effect still dominates the crowding-out effect from the higher real interest rate, government spending remains more expansionary in recessions in the quantitative model.

4.3 Degree of downward nominal wage rigidity

The central friction to deliver the state-dependent government spending multipliers is DNWR. This section investigates how the degree of DNWR, captured by the size of $\gamma$, can
Figure 3 compares our baseline simulation ($\gamma = 0.96$, solid lines) to the results from more rigid DNWR ($\gamma = 0.98$, dashed lines). When $\gamma$ rises, the government spending multiplier on impact increases from 1.71 to 1.89, and it is also persistently higher relative to the baseline. The row of $\gamma = 0.98$ in Table 2 summarizes the multiplier for output and consumption. The consumption multiplier is also persistently higher with $\gamma = 0.98$ throughout the horizon.

Given the same size of shocks in the discount factor, a higher degree of DNWR indicates that real wages stay at a higher level with $\gamma = 0.98$ than 0.96. As a result, DNWR binds for a longer period. When the real wage floor is higher, the unemployment is more severe, which implies a deeper recession. Under such a circumstance, a government spending increase becomes more effective to close the unemployment gap. In this simulation, the initial unemployment rate is 9.41% when $\gamma$ is 0.98 versus 6.45% in the baseline, but the same size of the government spending shock lowers the unemployment rate more when $\gamma = 0.98$, as shown in Figure 3. A larger decrease in unemployment brings forth a larger positive income effect, which makes consumption and hence output rise more than the base case. Table 2 shows that with $\gamma = 0.98$, the impact output multiplier rises to 1.89 (compared to 1.71 in the baseline with $\gamma = 0.96$). Also, more positive income effect with $\gamma = 0.98$ leads to a bigger consumption multiplier at 0.89 on impact (compared to 0.71 in the baseline).

4.4 Wealth Effects on Labor Supply

The baseline specification has a GHH preference and thus does not have the wealth effect on labor supply. In this section, we modify the model to adopt another commonly used preference, the KPR (King et al. (1988)) preference, which has the wealth effect on labor supply. We want to explore whether state-dependent multipliers are robust when the wealth effects on labor supply is present.

To proceed, the preference (1) is modified as:

$$\max \sum_{t=0}^{\infty} d_t \left[ c_t \left(1 - \chi n r_t^2 \right) \right]^{1-\sigma} \left[ 1 - \sigma \right]$$

(40)
To make the current preference comparable to the previous one, we re-calibrate \( \varphi \) here such that the elasticity of labor supply is 0.5 under both the two preference. The labor supply equation with the KPR preference is

\[
\frac{\chi \varphi (n_t^s)^{\varphi - 1}}{1 - \chi (n_t^s)^{\varphi}} = \frac{w_t}{c_t}.
\]

(41)

which differs from previous labor supply under GHH preference \((\chi \varphi (n_t^s)^{\varphi - 1} = w_t)\). Labor supply now does not only depend on real wages but also on consumption. A positive government spending shock indicates higher future taxes, creating a negative wealth effect that shifts the labor supply curve to the right.

An increase in labor supply alters the government spending effects mainly through its weakened effectiveness in reducing unemployment. Recall that the unemployment is caused by the gap between desired labor supply and labor demand for the binding real wage floor. With an increased in the desired labor supply, a spending increase is less effective in closing the unemployment gap and hence generates a smaller positive income effect relative to the case with the GHH preference. Figure 4 compares the responses to a government spending increase in the recession state under the two preferences. As shown in Figure 2, the positive income effect under GHH generates a positive consumption response despite the crowding-out of private demand by the rising real interest rate. In contrast under KPR, consumption falls instead as the weaker income effect is dominated by the negative consumption response to rising the real interest rate.

With crowding-out of private consumption, a government spending increase under KPR is less stimulative in aggregate demand than under GHH. The impact output multiplier falls to 0.65 under KPR (see Table 3), compared to 1.71 under GHH (the baseline, Table 1). In response to an overall smaller goods demand, Figure 4 shows that equilibrium labor and inflation increase less than under KPR, which results in a smaller increase in the real interest rate. Also, the real wage rate falls less initially under KPR because of a smaller increase in

\(^{13}\text{To make the initial recession state at } t = 0 \text{ as much similar to that with the baseline, we inject discount factor shocks from } t = -5 \text{ to 0 such that the unemployment rate is 6.31% and lagged real wages are 6.67% above the steady state. This is similar to the macroeconomic condition in the baseline: the unemployment rate is 6.45% and lagged real wages are 6.80% above the steady state.}\)
inflation, making the real wage floor falls less. In the later periods, however, the real wage under GHH rises more, because higher goods demand drives up the real wage rate more once DNWR dissipates.

From Table 3, we see that it remains the case that the output multipliers are bigger in recessions than in expansions. The difference, however, shrinks substantially in the presence of wealth effects on labor supply. Our comparison results highlight that the wealth effect of labor supply is important in affecting the differences in the government spending multipliers between recessions and expansions. The empirical importance of the negative wealth effect on labor supply to government spending shocks is yet to be carefully examined. In a DSGE model that accommodates various degrees of wealth effects on labor supply, Schmitt-Grohé and Uribe’s (2012) estimation finds the wealth effects on labor supply is almost nonexistent, consistent the GHH preference as assumed in our baseline.

4.5 Sizes of Government Spending Shocks

Our analysis so far shows that government spending in recessions can stimulate output and thus facilitate the recovery from a recession. One practical policy question to ask is how big a spending increase should be. Taking the advantage of nonlinear solutions, we can compare the government spending effects under the baseline 1-percent increase to an alternative 5-percent increase of the steady-state level.

Surprisingly, Table 2 shows that the a bigger stimulus (a 5% increase) indeed has a smaller output and consumption multiplier, although the differences with the 1% increase is small. To understand this result, we return to the two channels that cause government spending to be more expansionary in recessions. Intuitively, a bigger spending increase should add more to aggregate demand, increasing more the firms’ labor demand, and hence more effective in closing the gap between labor demand and desired labor supply. A larger reduction in unemployment should in turn bring forth a stronger positive income effect, leading private consumption to rise more.

In addition to reduced unemployment, a bigger current spending stimulus and hence a
bigger expected future spending increase however, drive up current inflation more, which induce the monetary authority to raise the nominal rate more to combat inflation. Consequently, the real interest rate rises much more with a 5% shock than a 1% shock, and hence consumption crowding-out is more severe with a 5% shock offsetting the stronger positive income effect from reduced unemployment.

Figure 5 compares the responses of the various economies, which start with the same recession state at time 0, but are injected by different sizes of spending stimulus. It can be seen that with a 5% spending increase, output returns to the steady state at 5 quarters after the recession begins, but it takes about 10 quarters with a 1% increase. From a quantitative perspective, the recovery paths between the two stimulus scenarios are very close. As analyzed, a 5% increases lower unemployment more. Without the stimulus, the unemployment rate is 6.45%; the 1% spending increase lowers this to about 6%, compared to less than 5% with a 5% spending increase. Despite being effective to lower unemployment, the consumption responses between the two scenarios are quite similar, mainly because of higher inflation and the real interest rate with the 5% spending case.

Overall the benefits of a bigger stimulus has to weigh against its costs. Although the two spending sizes have similar macroeconomic effects, our model only considers unrealistic lump-sum financing (see (21)). When deficit financing with distorting fiscal adjustments (such income tax rate hikes or government spending reversals) later, it is foreseeable to bring forth additional negative effects that counteract the initial expansionary effects of a spending increase. Our analysis here a bigger stimulus facilitates a recovery somewhat, but its effectiveness (measured by output multipliers) can be smaller than a smaller stimulus.

\[14\] Different from previous figures of impulse responses, this figure does not plot the difference with and without a government increase. Instead, it shows the combined responses to a contractionary discount factor shock plus a government spending shock.
5 Evidence of State-Dependent Government Spending Effects via DNWR

To show that the theoretical channels we propose in this paper is empirically important, we conduct a regime switching structural vector autoregression (SVAR) estimation following Auerbach and Gorodnichenko (2012b). Instead of estimating SVARs for each state of the economy separately, they estimate an SVAR with smooth transitions across recessions and expansions. With U.S. quarterly data from 1947Q1 to 2008Q4 for a system of government spending, tax revenues, and output, their estimates of the peak output multipliers within the first year after the shocks are between 0 and 0.5 in expansions and between 1 and 1.5 in recessions for the basic results.

The key predictions of our theoretical model is that real wage does not rise as much to a government spending increase in recessions than in expansions. Also, the reduced crowding out effect is reflected by the positive consumption response to a government spending increase in recessions. Thus, we modify and extend Auerbach and Gorodnichenko’s (2012b) specification to estimate a system of government spending, output, real wage rates, and consumption. Following their basic specification in Auerbach and Gorodnichenko (2012b), we estimate the SVAR model:

\[
X_t = [1 - F(z_{t-1})] \Pi_L(L)X_{t-1} + F(z_{t-1}) \Pi_R(L) + X_{t-1} + u_t, \quad u_t \sim N(0, \omega_t)
\]

\[
\Omega_t = \Omega_L (1 - F(z_{t-1})) + \Omega_R F(z_{t-1})
\]

\[
F(z_t) = \frac{\exp(-\gamma z_t)}{1 + \exp(-\gamma z_t)}, \quad (42)
\]

where \(X_t = [g_t, y_t, w_t, c_t]\), \(var(z_t) = 1\), \(E(z_t) = 0\), and \(\gamma = 1.5\), implying that the economy in recessions about 20% of the time. We use the same data definition for government spending and output as theirs, but the sample period is extended, covering 1947Q1 to 2016Q3. Private consumption is the real personal consumption expenditures on nondurables and ser-

---

15 Adding tax revenue, as in Auerbach and Gorodnichenko (2012b), does not affect the results much as presented here.
vices, and real wages are real hourly compensation in nonfarm business. We impose the identification assumption that government spending does not contemporaneously respond to output, wages, and consumption. Three lags are included in the estimation.

Figure 6 displays the impulse responses for a government spending shock in both the linear model and the regime-switching model with expansions and recessions. The shaded bands around point estimates are 90% confidence internals. The units of government spending, output, and consumption responses are periodic multipliers, in which percent deviations are converted to level deviations by the sample averages of each variable. The units of real wage responses are in percent deviation to a 1-percent increase in government spending.

The results from the linear model (circle lines) have a government spending peak multiplier around 0.6, which is at the low end of existing estimates that do not distinguish among states (e.g., Barro and Redlick (2011)). Although many VAR estimates find that a government spending increase leads to positive private consumption responses (e.g., Blanchard and Perotti (2002) and Gali et al. (2007)), our linear estimate with samples after the global financial crisis only finds a slightly positive but insignificant consumption response, and it turns negative in later periods. This result is also consistent with Barrow and Redlick’s (2011) finding using defense spending. Similar to consumption, our linear estimation finds that a government spending increase has slightly negative but insignificant response on real wages. The existing empirical evidence on the real wage response to a government spending increase is mixed. Some find insignificant real wage responses to a government spending increase (e.g., Rotemberg and Woodford (1992), Ramey and Shapiro (1998), and Ramey (2011) with war dates of predicting future defense spending increase), but some find significant negative responses (e.g., Burnside et al. (2004) using after-tax real compensation).

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16 Government spending is the sum of government consumption expenditure and gross government investment (NIPA Table 3.1, lines 21 and 39) minus consumption of fixed capital (NIPA Table 3.1, line 42). Output is the gross domestic product (TIPA Table 1.1.4, line 1). Private consumption is the sum of personal consumption expenditures on nondurable goods and services (NIPA Table 1.1.5, lines 5 and 6). All nominal variables are adjusted by the GDP deflator. Real wages are measured by the index of real hourly compensation in nonfarm business (2009=100, the BLS, PRS85006153).

17 We want to do some sensitivity on the empirical estimations. First, the ordering of $X_t = [g_t, y_t, w_t, c_t]$. Second, a more serious issue: The use of a structural VAR to estimate the government spending effects runs into the foresight problem that some government spending changes may be anticipated. Auerbach and Gorodnichenko (2012b) expand $X_t$ to include professional forecast to control for the expectations. They show that the results that government spending multipliers are bigger in recessions still hold. We may want to address the foresight issue as well.

18 When deflating with the producer price index, Ramey and Shapiro (1998) find that the real wage has significant negative response to a government spending increase initially but turn insignificant afterwards.
Like Auerbach and Gorodnichenko (2012b), we find state-dependent government spending effects. Our peak output multiplier rises to 1.2 in recessions and drops to 0.4 in expansions. Although the multiplier in expansions are similar to theirs (0.6), the multiplier in recessions is much smaller than their estimate (2.48). Since our sample differs from theirs mainly in additional data after the Great Recession, this suggests that government spending may be less effective in recent data. Aside from output, we also find that state-dependent responses of real wages and consumption. In expansions, the real wage response is minimal, similar to the result from the linear estimation. In recessions, however, we see that real wages respond negatively to a spending increase, consistent with theoretical prediction that real wages can turn negative in recessions in the short run, while they can be more positive in expansions (as shown in Figure 2). Similarly, the nonlinear estimation obtains significantly positive consumption responses in recessions, compared to much muted responses in expansions.

Although our estimation results do not match the quantitative differences implied by the theoretical responses, they basically line up with the key channels of DNWR in producing state-dependent government spending multipliers: 1) a smaller real wage increase (or even decline) in recessions due to binding DNWR, and 2) a more positive consumption response due to the income effects from reduced unemployment and reduced crowding out because of a smaller real interest rate rise. To keep the nonlinear model solution manageable, our theoretical model abstracts from several important aspects that can be also important for the quantitative effects of government spending. For example, the model does not have nominal wage rigidity. If incorporated, this can dampen the positive wage responses in expansions. Also, the model does not have commonly incorporated real sluggish adjustments, like consumption habit formation. If incorporated, this can smooth the dramatic consumption changes within the first few quarters in expansions.

6 Conclusion

In this paper, we demonstrate that downward nominal wage rigidity (DNWR) can generate government spending multipliers that are business cycle dependent. To this end, we build
a simple NK model in which DNWR can bind in recessions. We first obtain the analytical linear solution from its simplified version to show that government spending can be more stimulative in recessions than in expansions via two channels. First, government spending in recessions with DNWR induces a smaller increase in inflation and hence a smaller increase in nominal and real interest rates, producing a smaller crowding out than in expansions. Second, government spending in recessions reduces unemployment, raising households’ income and hence private demand, amplifying the expansionary effects of a spending increase.

The simulation from the quantitative model finds that the impact output multiplier is 1.71 in the simulated recession state (where the unemployment rate is 6.45%) and is 0.57 in the expansion state (which is the deterministic steady state with full employment). Despite the substantial difference in output multipliers, consumption responses in these two different states have the opposite signs: it has the usual theoretical negative response in standard DSGE models in the expansion state, but turns positive in the recession state. The positive consumption response does not rely on the existence of nonsavers or utility generation government consumption, our positive consumption response in expansions provides an explanation for the empirical positive consumption response to a government spending increase in empirical VAR evidence.

To verify whether the theoretical channels we outline are empirically relevant, we estimate state-dependent government spending effects. In addition to a higher government spending multiplier in recessions, our estimation finds that consumption responds positively to a spending increase while it is negative in expansions. Also, the real wage levels are lower to a government spending increase in recessions than in expansions. These results suggest that DNWR is likely to be empirically important in contributing to state-dependent spending multipliers.
Appendix A  Equilibrium conditions

\[
\lambda_t = (c_t - \chi n_t^{\sigma})^{-\sigma}
\]  \hspace{1cm} (A.1)

\[
\chi \phi n_t^{\sigma-1} = w_t
\]  \hspace{1cm} (A.2)

\[
\lambda_t = R_t E_t \frac{\beta_{t+1} \lambda_{t+1}}{\pi_{t+1}}
\]  \hspace{1cm} (A.3)

\[
m c_t = \frac{w_t}{a_t}
\]  \hspace{1cm} (A.4)

\[
\frac{P^*_t}{P_t} = \frac{\theta}{\theta - 1} k_{1t}
\]  \hspace{1cm} (A.5)

\[
k_{1t} = \lambda_t y_t m c_t + \omega E_t \beta_{t+1} k_{1t+1} \pi_{t+1}^\theta
\]  \hspace{1cm} (A.6)

\[
k_{2t} = \lambda_t y_t + \omega E_t \beta_{t+1} k_{2t+1} \pi_{t+1}^{\theta-1}
\]  \hspace{1cm} (A.7)

\[
\pi_t = \left[ \frac{1}{\omega} - \frac{1 - \omega}{\omega} \left( \frac{P^*_t}{P_t} \right)^{1-\theta} \right]^\frac{1}{1-\theta}
\]  \hspace{1cm} (A.8)

\[
y_t = \frac{a_t n_t}{\Delta_t}
\]  \hspace{1cm} (A.9)

\[
y_t = c_t + g_t
\]  \hspace{1cm} (A.10)

\[
\Delta_t = (1 - \omega) \left( \frac{P^*_t}{P_t} \right)^{-\theta} + \omega \pi_t^\theta \Delta_{t-1}
\]  \hspace{1cm} (A.11)

\[
R_t = \max(R \pi_t^{\alpha_1}, 1)
\]  \hspace{1cm} (A.12)

\[
\ln \frac{\beta_t}{\beta} = \rho^\beta \ln \frac{\beta_{t-1}}{\beta} + \epsilon_t^\beta
\]  \hspace{1cm} (A.13)

\[
\ln \frac{a_t}{a} = \rho^a \ln \frac{a_{t-1}}{a} + \epsilon_t^a
\]  \hspace{1cm} (A.14)

\[
\ln \frac{g_t}{g} = \rho^g \ln \frac{g_{t-1}}{g} + \epsilon_t^g
\]  \hspace{1cm} (A.15)
Appendix B  Analytic of the Linear Model

Appendix B.1  Proof of Proposition 1

When DWNR does not bind, an economy has full employment; i.e. \( n_t^* = n_t \) or \( u_t = 0 \) in (7). We can use (A.2), (A.4), and (A.9) to derive the marginal cost:

\[
\hat{mc}_t = \hat{w}_t = (\phi - 1)\hat{n}_t = (\phi - 1)\hat{y}_t. \tag{B.1}
\]

Then, using (B.1) in (30), the equilibrium system can be summarized by

\[
\hat{y}_t = E_t\hat{y}_{t+1} - \Psi(\alpha\hat{\pi}_t - E_t\hat{\pi}_{t+1}) + \theta_s\hat{g}_t - E_t\hat{\beta}_{t+1} - \Psi E_t\hat{\beta}_{t+1} \tag{B.2}
\]

\[
\hat{\pi}_t = \beta E_t\hat{\pi}_{t+1} + \frac{(1 - \omega)(1 - \omega\beta)(\phi - 1)}{\omega}\hat{y}_t. \tag{B.3}
\]

Let the full-employment solution (denoted by “\(*\”) take the form:

\[
\hat{y}_t^* = A^j_y\hat{g}_t + B^j_{\pi} E_t\hat{\beta}_{t+1}
\]

\[
\hat{\pi}_t^* = A^j_{\pi}\hat{g}_t + B^j_{\pi} E_t\hat{\beta}_{t+1}, \tag{B.4}
\]

where \( j \in \{E, R\} \), and E (R) indicates the states of an expansion (a recession). Given an \( i.i.d \) process of government spending (see (20)), the expected output and inflation are given by,

\[
E_t\hat{y}_{t+1}^* = B^j_{y} E_t\hat{\beta}_{t+2}
\]

\[
E_t\hat{\pi}_{t+1}^* = B^j_{\pi} E_t\hat{\beta}_{t+2}. \tag{B.5}
\]

According to Definition 1 and Assumption 1, \( E_t\hat{\beta}_{t+1} = b_l \) and \( E_t\hat{\beta}_{t+2} = 0.5b_L + 0.5b_H = 0 \) in expansions, and \( E_t\hat{\beta}_{t+1} = b_H \) and \( E_t\hat{\beta}_{t+2} = b_L \) in recessions. Apply these assumptions and substitute (B.4) and (B.5) to (B.2) and (B.3). Then, we obtain the solution of the following
form:

\[
A_y = A_y^E = A_y^R = \frac{\omega \theta s_g}{\omega + \Psi \alpha (1 - \omega)(1 - \omega \beta)(\varphi - 1)} > 0
\]

\[
A_\pi = A_\pi^E = A_\pi^R = \frac{-\theta s_g (1 - \omega)(1 - \omega \beta)(\varphi - 1)}{\omega + \Psi \alpha (1 - \omega)(1 - \omega \beta)(\varphi - 1)} > 0
\]

\[
B_y^E = \frac{-\omega}{\omega + \Psi \alpha (1 - \omega)(1 - \omega \beta)(\varphi - 1)} < 0
\]

\[
B_y^R = \frac{-\omega}{2\omega (1 + \beta) + \Psi (\alpha + 1)(1 - \omega)(1 - \omega \beta)(\varphi - 1)} < 0
\]

\[
B_\pi^E = \frac{-(1 - \omega)(1 - \omega \beta)(\varphi - 1)}{\omega + \Psi \alpha (1 - \omega)(1 - \omega \beta)(\varphi - 1)} < 0
\]

\[
B_\pi^R = \frac{-(1 - \omega)(1 - \omega \beta)(\varphi - 1)}{2\omega (1 + \beta) + \Psi (\alpha + 1)(1 - \omega)(1 - \omega \beta)(\varphi - 1)} < 0
\]

The government spending multiplier is:

\[
M_y = \frac{dy^*_t}{dt} = \frac{\hat{y}_t^Y G}{\hat{y}_t^G} = \frac{A_y^j}{s_g} = \frac{\omega \theta}{\omega + \Psi \alpha (1 - \omega)(1 - \omega \beta)(\varphi - 1)}, \quad j \in \{E, R\}. \tag{B.7}
\]

(B.7) shows that without DNWR binding, the fiscal multiplier in expansions and recessions are exactly the same.

**Appendix B.2  Proof of Proposition 2**

To derive the government spending multiplier in a recession where DNWR binds. We maintain Assumption 2 that the economy at \(t - 1\) has full employment and \(\hat{w}_{t-1} > 0\), and it is hit by a sufficiently large contractionary discount factor shock \((b_H)\) such that DNWR binds at \(t\). To solve the equilibrium with DNWR, substitute \(\hat{m}_c_t\) with \(\hat{w}_t\) in (30), which now equals \(\hat{w}_{t-1} - \hat{\pi}_t\), which yields the equilibrium conditions with DNWR:

\[
\hat{y}_t = E_t \hat{y}_{t+1} - \Psi (\alpha \hat{\pi}_t - E_t \hat{\pi}_{t+1}) + \theta s_g (\hat{g}_t - E_t \hat{g}_{t+1}) - \Psi E_t \hat{\beta}_{t+1} \tag{B.8}
\]

\[
\hat{\pi}_t = \beta E_t \hat{\pi}_{t+1} + \frac{(1 - \omega)(1 - \omega \beta)}{\omega} (\hat{w}_{t-1} - \hat{\pi}_t). \tag{B.9}
\]

Different from the full-employment equilibrium condition, the real wage rate from the last period \((\hat{w}_{t-1})\) plays a role in determining the current real wage as \(\hat{w}_{t-1}\) enters the state space.
as shown in (B.9). Thus, the solution takes the form of

\[
\hat{y}_t = E_y \hat{w}_{t-1} + F_y \hat{g}_t + H_y b_H \\
\hat{\pi}_t = E_\pi \hat{w}_{t-1} + F_\pi \hat{g}_t + H_\pi b_H. 
\] (B.10)

From Assumptions 1 and 2, once \(E_t \hat{\beta}_{t+1} = b_H, E_t \hat{\beta}_{t+2} = b_L\) with probability 1, and \(b_L\) does not trigger DNWR. As a result, the expected output and inflation are given by the full employment solution,

\[
E_t \hat{y}_{t+1} = B^y_b L \\
E_t \hat{\pi}_{t+1} = B^\pi_b L
\] (B.11)

Substitute (B.10) and (B.11) to (B.8) and (B.9),

\[
E_y = -\Psi \alpha (1 - \omega)(1 - \omega \beta) \frac{\omega}{\omega + (1 - \omega)(1 - \omega \beta)} < 0 \\
E_\pi = \frac{(1 - \omega)(1 - \omega \beta)}{\omega + (1 - \omega)(1 - \omega \beta)} > 0 \\
F_y = \theta s_g > 0 \\
F_\pi = 0 \\
H_y = \text{complicated} \\
H_\pi = \text{complicated} 
\] (B.12)

In recessions with DNWR, the government spending multiplier is

\[
M_y^{DNWR} = \frac{dy}{dg_t} = \frac{\hat{y}_t Y}{\hat{g}_t G} = \frac{F_y}{s_g} = \theta 
\] (B.13)

To compare the two multipliers in the state with and without DNWR binding, we subtract \(M_y\) as implied in (B.7) from \(M_y^{DNWR}\) and get

\[
M_y^{DNWR} - M_y = \theta - \frac{\omega \theta}{\omega + \Delta} = \theta \left( 1 - \frac{\omega}{\omega + \Delta} \right) > 0
\] (B.14)
where $\Delta \equiv \Psi \alpha (1 - \omega)(1 - \omega \beta)(\varphi - 1) > 0$. Thus, the government spending multipliers in recessions with DNWR is greater than the multiplier in expansions.

**Appendix B.3 Proof of Proposition 3**

Unemployment, defined as the difference between labor supply and the actual number of hours worked, is given by (7). From household’s labor supply equation, (8), and the production function, (18), the desired linearized labor supply is $\hat{n}_t = \frac{1}{\varphi - 1} \hat{w}_t$ but the actual linearized labor worked is $\hat{n}_t = \hat{y}_t$. Use the solution in (B.12), we can solve for unemployment to get

$$\hat{u}_t = \frac{1}{\varphi - 1} (\hat{w}_{t-1} - \hat{\pi}_t) - \hat{y}_t$$

(B.15)

$$\hat{y}_t$$

$$\hat{u}_t$$

$$\hat{y}_t$$

where

$$\Gamma_u^w = \frac{1 - E_y}{\varphi} - E_y = \frac{\omega + \Psi \alpha (1 - \omega)(1 - \omega \beta)(\varphi - 1)}{(\varphi - 1)[\omega + (1 - \omega)(1 - \omega \beta)]} > 0$$

$$\Gamma_u^g = -\frac{E_y}{\varphi - 1} - F_y = -\theta s_g < 0$$

(B.16)

$$\Gamma_u^\beta = -\frac{H_y}{\varphi - 1} - H_y.$$

Thus, in recessions with binding DNWR, a government spending increase decreases unemployment, as $\frac{d\hat{u}_t}{d\hat{y}_t} = \Gamma_u^g < 0$. In expansions, where DNWR does not bind and the economy is in full employment, a government spending increase has no effect on unemployment.

Next, we solve for the real interest rate using $\hat{r}_t = \alpha \hat{\pi}_t - E_t \hat{\pi}_{t+1}$. In recessions with binding DNWR, substitute (B.11) and (B.12) to get

$$\hat{r}_t = \alpha \hat{\pi}_t - E_t \hat{\pi}_{t+1}$$

(B.17)

$$\hat{r}_t$$

$$\alpha \hat{\pi}_t$$

$$E_t \hat{\pi}_{t+1}$$
where

\[ \Gamma_w = \alpha E \pi = \frac{\alpha (1 - \omega)(1 - \omega \beta)}{\omega + (1 - \omega)(1 - \omega \beta)} > 0 \]
\[ \Gamma_g = \alpha F \pi = 0 \]
\[ \Gamma_\beta = \alpha H \pi + B^E \pi. \]  

From (B.18), we see that a government spending increase does not increase the real interest rate in recessions with binding DNWR,

\[ \frac{d\hat{r}_t}{d\hat{g}_t} = \Gamma_g = 0 \]  

In expansions, we use the solutions from (B.6) to solve for the real interest rate,

\[ \hat{r}_t = \alpha \hat{\pi}_t - E_t \hat{\pi}_{t+1} = \Gamma_g \hat{g}_t + \Gamma_\beta b_L, \]  

where

\[ \Gamma_g = \alpha A \pi = \frac{\theta s_g (1 - \omega)(1 - \omega \beta) (\phi - 1)}{\omega + \Psi \alpha (1 - \omega)(1 - \omega \beta) (\phi - 1)} > 0 \]
\[ \Gamma_\beta = B^E \pi < 0 \]  

From (B.21), we see that a government spending increase increases the real interest rate in expansions.

\[ \frac{d\hat{r}_t}{d\hat{g}_t} = \Gamma_g > 0. \]

Appendix C  Numerical Method

When solving the nonlinear model, the state space is \( S_t = \{ \beta_t, g_t, \Delta_{t-1}, w_{t-1} \} \). Define the decision rules for hours as \( n_t = f^n(S_t) \), \( k_{1t} = f^{k_1}(S_t) \), and \( k_{2t} = f^{k_2}(S_t) \). The decision rules are solved as follows.

1. Define the grid points by discretizing the state space. Make initial guesses for \( f^n_0, f^{k_1}_0 \),
and $f_{k_2}^{k_2}$ over the state space.

2. At each grid point, solve the nonlinear model and obtain the updated rules $f_i^n$, $f_i^{k_1}$, and $f_i^{k_2}$ using the given rules $f_{i-1}^n$, $f_{i-1}^{k_1}$, and $f_{i-1}^{k_2}$:

(a) Derive $P_t^*$ and $\pi_t$, using (A.5) and (A.8).

(b) Given $w_{t-1}$ and $\pi_t$, compute $\gamma \frac{w_{t-1}}{\pi_t}$, and compare it with the full employment wage $w_t^*$. If $\gamma \frac{w_{t-1}}{\pi_t} \leq w_t^*$, $w_t = w_t^*$; if $\gamma \frac{w_{t-1}}{\pi_t} < w_t^*$, $w_t = \gamma \frac{w_{t-1}}{\pi_t}$.

(c) Compute $\Delta_t$, $y_t$, $c_t$, $mc_t$, and $\lambda_t$ using (A.11), (A.9), (A.10), (A.4), and (A.1).

(d) Derive the desired labor supply $n_t^*$ from (A.2), and then the unemployment rate is defined as $\frac{n_t^* - n_t}{n_t^*} \times 100\%$.

(e) Given $f_{i-1}^\pi$, obtain the nominal interest rate $R_t$ from equation (A.12). If $R^\pi_t < 1$, use 1 as the nominal interest rate.

(f) Use linear interpolation to obtain $f_{i+1}^n(S_{t+1})$, $f_{i+1}^{k_1}(S_{t+1})$, and $f_{i+1}^{k_2}(S_{t+1})$, where $S_{t+1} = (\beta_{t+1}, g_{t+1}, \Delta_t, w_t)$, where $\beta_{t+1}$ and $g_{t+1}$ are updated according to the AR(1) processes from (A.13) and (A.15). Then follow the above steps to solve $\lambda_{t+1}$, $\pi_{t+1}$, $k_{t+1}$, and $k_{2t+1}$.

(g) Update the decision rules $f_i^n$, $f_i^{k_1}$, and $f_i^{k_2}$ using (A.3), (A.6), and (A.7).

3. Check convergence of the decision rules. If $|f_i^n - f_{i-1}^n|$, or $|f_i^{k_1} - f_{i-1}^{k_1}|$, or $|f_i^{k_2} - f_{i-1}^{k_2}|$ are above the desired tolerance (set to $1e-7$), go back to step 2; otherwise, $f_i^n$, $f_i^{k_1}$, and $f_i^{k_2}$ are the decision rules.
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<th>20 quarters</th>
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<td>-0.11</td>
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Table 1: Baseline simulations: output and consumption multipliers

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<tbody>
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<td>5% g shock</td>
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<td>baseline</td>
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<tr>
<td>5% g shock</td>
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</table>

Table 2: Simulations with more rigid DNWR or more spending increase: output and consumption multipliers in recessions

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<th>20 quarters</th>
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Table 3: Sensitivity analysis: the KPR preference.
Figure 1: Nominal wage rigidity in the U.S. Labor variables are from the Bureau of Labor Statistics. See data description in footnote 4.
Figure 2: Impulse responses to a government spending increase in recessions and expansions. Except for unemployment and discount factor, the y-axis is the response differences between a path with and without a government spending shock, scaled by the deterministic steady-state values. The unemployment rate is in level difference, and the discount factor is in percent deviation from the steady state.
Figure 3: Responses in the recession state: different degrees of DNWR. See Figure 5 for axis units.

Figure 4: Responses in the recession state: KPR vs. GHH preference. See Figure 5 for axis units.
Figure 5: Economic performance in the recession state with two different sizes of government spending increases. All variables are in percent deviation from the steady state under the combined two shocks: the same contractionary discount factor shock plus two different government spending shocks at time 0.

Figure 6: Impulse responses in the linear model, expansions, and recessions
References


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